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PROGRAMMABLE DATA ELEMENT QUEUING, HANDLING PROCESSING AND LINKING DEVICE INTEGRATED INTO AN OBJECT IDENTIFICATION AND ATTRIBUTE ACQUISITION SYSTEM

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CROSS-REFERENCE TO RELATED U.S. APPLICATIONS

This is a Continuation of copending Application No. 09/990,585 filed November 21, 2001 which is a Continuation-in-Part of: copending Application Serial No. 09/999,687 filed October 31, 2001; copending Application Serial No. 09/954,477 filed September 17, 2001; copending Application Serial No. 09/883,130 filed June 15, 2001, which is a Continuation-in-Part of Application Serial No. 09/781,665 filed February 12, 2001; copending Application Serial No. 09/780,027 filed February 9, 2001; copending Application Serial No. 09/721,885 filed November 24, 2000; Application Serial No. 09/327,756 filed June 7, 1999; and International Application Serial No. PCT/US00/15624 filed June 7, 2000, published as WIPO WO 00/75856 A1; each said application being commonly owned by Assignee, Metrologic Instruments, Inc., of Blackwood, New Jersey, and incorporated herein by reference as if fully set forth herein in its entirety.

BACKGROUND OF THE INVENTION

Field of Invention

The present invention relates generally to improved methods of and apparatus for illuminating moving as well as stationary objects, such as parcels, during image formation and detection operations, and also to improved methods of and apparatus and instruments for

acquiring and analyzing information about the physical attributes of such objects using such improved methods of object illumination, and digital image analysis.

Brief Description Of The State Of Knowledge In The Art

The use of image-based bar code symbol readers and scanners is well known in the field of auto-identification. Examples of image-based bar code symbol reading/scanning systems include, for example, hand-hand scanners, point-of-sale (POS) scanners, and industrial-type conveyor scanning systems.

Presently, most commercial image-based bar code symbol readers are constructed using charge-coupled device (CCD) image sensing/detecting technology. Unlike laser-based scanning technology, CCD imaging technology has particular illumination requirements which differ from application to application.

Most prior art CCD-based image scanners, employed in conveyor-type package identification systems, require high-pressure sodium, metal halide or halogen lamps and large, heavy and expensive parabolic or elliptical reflectors to produce sufficient light intensities to illuminate the large depth of field scanning fields supported by such industrial scanning systems. Even when the light from such lamps is collimated or focused using such reflectors, light strikes the target object other than where the imaging optics of the CCD-based camera are viewing. Since only a small fraction of the lamps output power is used to illuminate the CCD camera's field of view, the total output power of the lamps must be very high to obtain the illumination levels required along the field of view of the CCD camera. The balance of the output illumination power is simply wasted in the form of heat.

While US Patent No. 4,963,756 to Quan et al disclose a prior art CCD-based hand-held image scanner using a laser source and Scheimpflug optics for focusing a planar laser illumination beam reflected off a bar code symbol onto a 2-D CCD image detector, US Patent No. 5,192,856 to Schaham discloses a CCD-based hand-held image scanner which uses a LED and a cylindrical lens to produce a planar beam of LED-based illumination for illuminating a bar code symbol on an object, and cylindrical optics mounted in front a linear CCD image detector for projecting a narrow a field of view about the planar beam of illumination, thereby enabling collection and focusing of light reflected off the bar code symbol onto the linear CCD image detector.

Also, in U.S. Provisional Application No. 60/190,273 entitled "Coplanar Camera" filed March 17, 2000, by Chaleff et al., and published by WIPO on September 27, 2001 as part of WIPO Publication No. WO 01/72028 A1, both being incorporated herein by reference, there is disclosed a CCD camera system which uses an array of LEDs and a single apertured Fresnel-

type cylindrical lens element to produce a planar beam of illumination for illuminating a bar code symbol on an object, and a linear CCD image detector mounted behind the apertured Fresnel-type cylindrical lens element so as to provide the linear CCD image detector with a field of view that is arranged with the planar extent of planar beam of LED-based illumination.

However, most prior art CCD-based hand-held image scanners use an array of light emitting diodes (LEDs) to flood the field of view of the imaging optics in such scanning systems. A large percentage of the output illumination from these LED sources is dispersed to regions other than the field of view of the scanning system. Consequently, only a small percentage of the illumination is actually collected by the imaging optics of the system, Examples of prior art CCD hand-held image scanners employing LED illumination arrangements are disclosed in US Patent Nos. Re. 36,528, 5,777,314, 5,756,981, 5,627,358, 5,484,994, 5,786,582, and 6,123,261 to Roustaei, each assigned to Symbol Technologies, Inc. and incorporated herein by reference in its entirety. In such prior art CCD-based hand-held image scanners, an array of LEDs are mounted in a scanning head in front of a CCD-based image sensor that is provided with a cylindrical lens assembly. The LEDs are arranged at an angular orientation relative to a central axis passing through the scanning head so that a fan of light is emitted through the light transmission aperture thereof that expands with increasing distance away from the LEDs. The intended purpose of this LED illumination arrangement is to increase the "angular distance" and "depth of field" of CCD-based bar code symbol readers. However, even with such improvements in LED illumination techniques, the working distance of such hand-held CCD scanners can only be extended by using more LEDs within the scanning head of such scanners to produce greater illumination output therefrom, thereby increasing the cost, size and weight of such scanning devices.

Similarly, prior art "hold-under" and "hands-free presentation" type CCD-based image scanners suffer from shortcomings and drawbacks similar to those associated with prior art CCD-based hand-held image scanners.

Recently, there have been some technological advances made involving the use of laser illumination techniques in CCD-based image capture systems to avoid the shortcomings and drawbacks associated with using sodium-vapor illumination equipment, discussed above. In particular, US Patent No. 5,988,506 (assigned to Galore Scantec Ltd.), incorporated herein by reference, discloses the use of a cylindrical lens to generate from a single visible laser diode (VLD) a narrow focused line of laser light which fans out an angle sufficient to fully illuminate a code pattern at a working distance. As disclosed, mirrors can be used to fold the laser illumination beam towards the code pattern to be illuminated in the working range of the system. Also, a horizontal linear lens array consisting of lenses is mounted before a linear CCD image array, to receive diffused reflected laser light from the code symbol surface. Each single lens in the linear lens array forms its own image of the code line illuminated by the laser illumination

beam. Also, subaperture diaphragms are required in the CCD array plane to (i) differentiate image fields, (ii) prevent diffused reflected laser light from passing through a lens and striking the image fields of neighboring lenses, and (iii) generate partially-overlapping fields of view from each of the neighboring elements in the lens array. However, while avoiding the use of external sodium vapor illumination equipment, this prior art laser-illuminated CCD-based image capture system suffers from several significant shortcomings and drawbacks. In particular, it requires very complex image forming optics which makes this system design difficult and expensive to manufacture, and imposes a number of undesirable constraints which are very difficult to satisfy when constructing an auto-focus/auto-zoom image acquisition and analysis system for use in demanding applications.

When detecting images of target objects illuminated by a coherent illumination source (e.g. a VLD), "speckle" (i.e. substrate or paper) noise is typically modulated onto the laser illumination beam during reflection/scattering, and ultimately speckle-noise patterns are produced at the CCD image detection array, severely reducing the signal-to-noise (SNR) ratio of the CCD camera system. In general, speckle-noise patterns are generated whenever the phase of the optical field is randomly modulated. The prior art system disclosed in US Patent No. 5,988,506 fails to provide any way of, or means for reducing speckle-noise patterns produced at its CCD image detector thereof, by its coherent laser illumination source.

The problem of speckle-noise patterns in laser scanning systems is mathematically analyzed in the twenty-five (25) slide show entitled "Speckle Noise and Laser Scanning Systems" by Sasa Kresic-Juric, Emanuel Marom and Leonard Bergstein, of Symbol Technologies, Holtsville, NY, published at http://www.ima.umn.edu/industrial/99-2000/kresic/sld001.htm, and incorporated herein by reference. Notably, Slide 11/25 of this WWW publication summaries two generally well known methods of reducing speckle-noise by superimposing statistically independent (time-varying) speckle-noise patterns: (1) using multiple laser beams to illuminate different regions of the speckle-noise scattering plane (i.e. object); or (2) using multiple laser beams with different wavelengths to illuminate the scattering plane. Also, the celebrated textbook by J.C. Dainty, et al, entitled "Laser Speckle and Related Phenomena" (Second edition), published by Springer-Verlag, 1994, incorporated herein by reference, describes a collection of techniques which have been developed by others over the years in effort to reduce speckle-noise patterns in diverse application environments.

However, the prior art generally fails to disclose, teach or suggest how such prior art speckle-reduction techniques might be successfully practiced in laser illuminated CCD-based camera systems.

Thus, there is a great need in the art for an improved method of and apparatus for illuminating the surface of objects during image formation and detection operations, and also an

improved method of and apparatus for producing digital images using such improved methods object illumination, while avoiding the shortcomings and drawbacks of prior art illumination, imaging and scanning systems and related methodologies.

OBJECTS AND SUMMARY OF THE PRESENT INVENTION

Accordingly, a primary object of the present invention is to provide an improved method of and system for illuminating the surface of objects during image formation and detection operations and also improved methods of and systems for producing digital images using such improved methods object illumination, while avoiding the shortcomings and drawbacks of prior art systems and methodologies.

Another object of the present invention is to provide such an improved method of and system for illuminating the surface of objects using a linear array of laser light emitting devices configured together to produce a substantially planar beam of laser illumination which extends in substantially the same plane as the field of view of the linear array of electronic image detection cells of the system, along at least a portion of its optical path within its working distance.

Another object of the present invention is to provide such an improved method of and system for producing digital images of objects using a visible laser diode array for producing a planar laser illumination beam for illuminating the surfaces of such objects, and also an electronic image detection array for detecting laser light reflected off the illuminated objects during illumination and imaging operations.

Another object of the present invention is to provide an improved method of and system for illuminating the surfaces of object to be imaged, using an array of planar laser illumination modules which employ VLDs that are smaller, and cheaper, run cooler, draw less power, have longer lifetimes, and require simpler optics (i.e. because the spectral bandwidths of VLDs are very small compared to the visible portion of the electromagnetic spectrum).

Another object of the present invention is to provide such an improved method of and system for illuminating the surfaces of objects to be imaged, wherein the VLD concentrates all of its output power into a thin laser beam illumination plane which spatially coincides exactly with the field of view of the imaging optics of the system, so very little light energy is wasted.

Another object of the present invention is to provide a planar laser illumination and imaging (PLIIM) system, wherein the working distance of the system can be easily extended by simply changing the beam focusing and imaging optics, and without increasing the output power of the visible laser diode (VLD) sources employed therein.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein each planar laser illumination beam is focused so that the minimum

width thereof (e.g. 0.6 mm along its non-spreading direction) occurs at a point or plane which is the farthest object distance at which the system is designed to capture images.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein a fixed focal length imaging subsystem is employed, and the laser beam focusing technique of the present invention helps compensate for decreases in the power density of the incident planar illumination beam due to the fact that the width of the planar laser illumination beam increases for increasing distances away from the imaging subsystem.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein a variable focal length (i.e. zoom) imaging subsystem is employed, and the laser beam focusing technique of the present invention helps compensate for (i) decreases in the power density of the incident illumination beam due to the fact that the width of the planar laser illumination beam (i.e. beamwidth) along the direction of the beam's planar extent increases for increasing distances away from the imaging subsystem, and (ii) any $1/r^2$ type losses that would typically occur when using the planar laser illumination beam of the present invention.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein scanned objects need only be illuminated along a single plane which is coplanar with a planar section of the field of view of the image formation and detection module being used in the PLIIM system.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein low-power, light-weight, high-response, ultra-compact, high-efficiency solid-state illumination producing devices, such as visible laser diodes (VLDs), are used to selectively illuminate ultra-narrow sections of a target object during image formation and detection operations, in contrast with high-power, low-response, heavy-weight, bulky, low-efficiency lighting equipment (e.g. sodium vapor lights) required by prior art illumination and image detection systems.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein the planar laser illumination technique enables modulation of the spatial and/or temporal intensity of the transmitted planar laser illumination beam, and use of simple (i.e. substantially monochromatic) lens designs for substantially monochromatic optical illumination and image formation and detection operations.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein special measures are undertaken to ensure that (i) a minimum safe distance is maintained between the VLDs in each PLIM and the user's eyes using a light shield, and (ii) the planar laser illumination beam is prevented from directly scattering into the FOV of the image formation and detection module within the system housing.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein the planar laser illumination beam and the field of view of the image formation and detection module do not overlap on any optical surface within the PLIIM system.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein the planar laser illumination beams are permitted to spatially overlap with the FOV of the imaging lens of the PLIIM only outside of the system housing, measured at a particular point beyond the light transmission window, through which the FOV is projected.

Another object of the present invention is to provide a planar laser illumination (PLIM) system for use in illuminating objects being imaged.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein the monochromatic imaging module is realized as an array of electronic image detection cells (e.g. CCD).

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein the planar laser illumination arrays (PLIAs) and the image formation and detection (IFD) module (i.e. camera module) are mounted in strict optical alignment on an optical bench such that there is substantially no relative motion, caused by vibration or temperature changes, is permitted between the imaging lens within the IFD module and the VLD/cylindrical lens assemblies within the PLIAs.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein the imaging module is realized as a photographic image recording module.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein the imaging module is realized as an array of electronic image detection cells (e.g. CCD) having short integration time settings for performing high-speed image capture operations.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein a pair of planar laser illumination arrays are mounted about an image formation and detection module having a field of view, so as to produce a substantially planar laser illumination beam which is coplanar with the field of view during object illumination and imaging operations.

Another object of the present invention is to provide a planar laser illumination and imaging system, wherein an image formation and detection module projects a field of view through a first light transmission aperture formed in the system housing, and a pair of planar laser illumination arrays project a pair of planar laser illumination beams through second set of light transmission apertures which are optically isolated from the first light transmission aperture to prevent laser beam scattering within the housing of the system.

Another object of the present invention is to provide a planar laser illumination and imaging system, the principle of Gaussian summation of light intensity distributions is employed to produce a planar laser illumination beam having a power density across the width the beam which is substantially the same for both far and near fields of the system.

Another object of the present invention is to provide an improved method of and system for producing digital images of objects using planar laser illumination beams and electronic image detection arrays.

Another object of the present invention is to provide an improved method of and system for producing a planar laser illumination beam to illuminate the surface of objects and electronically detecting light reflected off the illuminated objects during planar laser beam illumination operations.

Another object of the present invention is to provide a hand-held laser illuminated image detection and processing device for use in reading bar code symbols and other character strings.

Another object of the present invention is to provide an improved method of and system for producing images of objects by focusing a planar laser illumination beam within the field of view of an imaging lens so that the minimum width thereof along its non-spreading direction occurs at the farthest object distance of the imaging lens.

Another object of the present invention is to provide planar laser illumination modules (PLIMs) for use in electronic imaging systems, and methods of designing and manufacturing the same.

Another object of the present invention is to provide a Planar Laser Illumination Module (PLIM) for producing substantially planar laser beams (PLIBs) using a linear diverging lens having the appearance of a prism with a relatively sharp radius at the apex, capable of expanding a laser beam in only one direction.

Another object of the present invention is to provide a planar laser illumination module (PLIM) comprising an optical arrangement employs a convex reflector or a concave lens to spread a laser beam radially and also a cylindrical-concave reflector to converge the beam linearly to project a laser line.

Another object of the present invention is to provide a planar laser illumination module (PLIM) comprising a visible laser diode (VLD), a pair of small cylindrical (i.e. PCX and PCV) lenses mounted within a lens barrel of compact construction, permitting independent adjustment of the lenses along both translational and rotational directions, thereby enabling the generation of a substantially planar laser beam therefrom.

Another object of the present invention is to provide a multi-axis VLD mounting assembly embodied within planar laser illumination array (PLIA) to achieve a desired degree of uniformity in the power density along the PLIB generated from said PLIA.

Another object of the present invention is to provide a multi-axial VLD mounting assembly within a PLIM so that (1) the PLIM can be adjustably tilted about the optical axis of its VLD, by at least a few degrees measured from the horizontal reference plane as shown in Fig. 1B4, and so that (2) each VLD block can be adjustably pitched forward for alignment with other VLD beams.

Another object of the present invention is to provide planar laser illumination arrays (PLIAs) for use in electronic imaging systems, and methods of designing and manufacturing the same.

Another object of the present invention is to provide a unitary object attribute (i.e. feature) acquisition and analysis system completely contained within in a single housing of compact lightweight construction (e.g. less than 40 pounds).

Another object of the present invention is to provide such a unitary object attribute acquisition and analysis system, which is capable of (1) acquiring and analyzing in real-time the physical attributes of objects such as, for example, (i) the surface reflectivity characteristics of objects, (ii) geometrical characteristics of objects, including shape measurement, (iii) the motion (i.e. trajectory) and velocity of objects, as well as (iv) bar code symbol, textual, and other information-bearing structures disposed thereon, and (2) generating information structures representative thereof for use in diverse applications including, for example, object identification, tracking, and/or transportation/routing operations.

Another object of the present invention is to provide such a unitary object attribute acquisition and analysis system, wherein a multi-wavelength (i.e. color-sensitive) Laser Doppler Imaging and Profiling (LDIP) subsystem is provided for acquiring and analyzing (in real-time) the physical attributes of objects such as, for example, (i) the surface reflectivity characteristics of objects, (ii) geometrical characteristics of objects, including shape measurement, and (iii) the motion (i.e. trajectory) and velocity of objects.

Another object of the present invention is to provide such a unitary object attribute acquisition and analysis system, wherein an image formation and detection (i.e. camera) subsystem is provided having (i) a planar laser illumination and imaging (PLIIM) subsystem, (ii) intelligent auto-focus/auto-zoom imaging optics, and (iii) a high-speed electronic image detection array with height/velocity-driven photo-integration time control to ensure the capture of images having constant image resolution (i.e. constant dpi) independent of package height.

Another object of the present invention is to provide such a unitary object attribute acquisition and analysis system, wherein an advanced image-based bar code symbol decoder is provided for reading 1-D and 2-D bar code symbol labels on objects, and an advanced optical character recognition (OCR) processor is provided for reading textual information, such as

alphanumeric character strings, representative within digital images that have been captured and lifted from the system.

Another object of the present invention is to provide such a unitary object attribute acquisition and analysis system for use in the high-speed parcel, postal and material handling industries.

Another object of the present invention is to provide such a unitary object attribute acquisition and analysis system, which is capable of being used to identify, track and route packages, as well as identify individuals for security and personnel control applications.

Another object of the present invention is to provide such a unitary object attribute acquisition and analysis system which enables bar code symbol reading of linear and two-dimensional bar codes, OCR-compatible image lifting, dimensioning, singulation, object (e.g. package) position and velocity measurement, and label-to-parcel tracking from a single overhead-mounted housing measuring less than or equal to 20 inches in width, 20 inches in length, and 8 inches in height.

Another object of the present invention is to provide such a unitary object attribute acquisition and analysis system which employs a built-in source for producing a planar laser illumination beam that is coplanar with the field of view (FOV) of the imaging optics used to form images on an electronic image detection array, thereby eliminating the need for large, complex, high-power power consuming sodium vapor lighting equipment used in conjunction with most industrial CCD cameras.

Another object of the present invention is to provide such a unitary object attribute acquisition and analysis system, wherein the all-in-one (i.e. unitary) construction simplifies installation, connectivity, and reliability for customers as it utilizes a single input cable for supplying input (AC) power and a single output cable for outputting digital data to host systems.

Another object of the present invention is to provide such a unitary object attribute acquisition and analysis system, wherein such systems can be configured to construct multi-sided tunnel-type imaging systems, used in airline baggage-handling systems, as well as in postal and parcel identification, dimensioning and sortation systems.

Another object of the present invention is to provide such a unitary object attribute acquisition and analysis system, for use in (i) automatic checkout solutions installed within retail shopping environments (e.g. supermarkets), (ii) security and people analysis applications, (iii) object and/or material identification and inspection systems, as well as (iv) diverse portable, in-counter and fixed applications in virtual any industry.

Another object of the present invention is to provide such a unitary object attribute acquisition and analysis system in the form of a high-speed object identification and attribute acquisition system, wherein the PLIIM subsystem projects a field of view through a first light

transmission aperture formed in the system housing, and a pair of planar laser illumination beams through second and third light transmission apertures which are optically isolated from the first light transmission aperture to prevent laser beam scattering within the housing of the system, and the LDIP subsystem projects a pair of laser beams at different angles through a fourth light transmission aperture.

Another object of the present invention is to provide a fully automated unitary-type package identification and measuring system contained within a single housing or enclosure, wherein a PLIIM-based scanning subsystem is used to read bar codes on packages passing below or near the system, while a package dimensioning subsystem is used to capture information about attributes (i.e. features) about the package prior to being identified.

Another object of the present invention is to provide such an automated package identification and measuring system, wherein Laser Detecting And Ranging (LADAR) based scanning methods are used to capture two-dimensional range data maps of the space above a conveyor belt structure, and two-dimensional image contour tracing techniques and corner point reduction techniques are used to extract package dimension data therefrom.

Another object of the present invention is to provide such a unitary system, wherein the package velocity is automatically computed using package range data collected by a pair of amplitude-modulated (AM) laser beams projected at different angular projections over the conveyor belt.

Another object of the present invention is to provide such a system in which the lasers beams having multiple wavelengths are used to sense packages having a wide range of reflectivity characteristics.

Another object of the present invention is to provide an improved image-based hand-held scanners, body-wearable scanners, presentation-type scanners, and hold-under scanners which embody the PLIIM subsystem of the present invention.

Another object of the present invention is to provide a planar laser illumination and imaging (PLIIM) system which employs high-resolution wavefront control methods and devices to reduce the power of speckle-noise patterns within digital images acquired by the system.

Another object of the present invention is to provide such a PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components on the time-frequency domain are optically generated using principles based on wavefront spatio-temporal dynamics.

Another object of the present invention is to provide such a PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components on the time-frequency domain are optically generated using principles based on wavefront non-linear dynamics.

Another object of the present invention is to provide such a PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components on the spatial-frequency domain are optically generated using principles based on wavefront spatio-temporal dynamics.

Another object of the present invention is to provide such a PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components on the spatial-frequency domain are optically generated using principles based on wavefront non-linear dynamics.

Another object of the present invention is to provide such a PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components are optically generated using diverse electro-optical devices including, for example, micro-electro-mechanical devices (MEMs) (e.g. deformable micro-mirrors), optically-addressed liquid crystal (LC) light valves, liquid crystal (LC) phase modulators, micro-oscillating reflectors (e.g. mirrors or spectrally-tuned polarizing reflective CLC film material), micro-oscillating refractive-type phase modulators, micro-oscillating diffractive-type micro-oscillators, as well as rotating phase modulation discs, bands, rings and the like.

Another object of the present invention is to provide a novel planar laser illumination and imaging (PLIIM) system and method which employs a planar laser illumination array (PLIA) and electronic image detection array which cooperate to effectively reduce the speckle-noise pattern observed at the image detection array of the PLIIM system by reducing or destroying either (i) the spatial and/or temporal coherence of the planar laser illumination beams (PLIBs) produced by the PLIAs within the PLIIM system, or (ii) the spatial and/or temporal coherence of the planar laser illumination beams (PLIBs) that are reflected/scattered off the target and received by the image formation and detection (IFD) subsystem within the PLIIM system.

Another object of the present invention is to provide a first generalized method of speckle-noise pattern reduction and particular forms of apparatus therefor based on reducing the spatial-coherence of the planar laser illumination beam before it illuminates the target object by applying spatial phase modulation techniques during the transmission of the PLIB towards the target.

Another object of the present invention is to provide such a method and apparatus, based on the principle of spatially phase modulating the transmitted planar laser illumination beam (PLIB) prior to illuminating a target object (e.g. package) therewith so that the object is illuminated with a spatially coherent-reduced planar laser beam and, as a result, numerous substantially different time-varying speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these speckle-noise patterns to be temporally averaged and possibly spatially averaged

over the photo-integration time period and the RMS power of observable speckle-noise pattern reduced.

Another object of the present invention is to provide a novel method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the method involves modulating the spatial phase of the composite-type "transmitted" planar laser illumination beam (PLIB) prior to illuminating an object (e.g. package) therewith so that the object is illuminated with a spatially coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array in the IFD subsystem, thereby allowing these speckle-noise patterns to be temporally averaged and/or spatially averaged and the observable speckle-noise pattern reduced.

Another object of the present invention is to provide such a method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein (i) the spatial phase of the transmitted PLIB is modulated along the planar extent thereof according to a spatial phase modulation function (SPMF) so as to modulate the phase along the wavefront of the PLIB and produce numerous substantially different time-varying speckle-noise patterns to occur at the image detection array of the IFD Subsystem during the photo-integration time period of the image detection array thereof, and also (ii) the numerous time-varying speckle-noise patterns produced at the image detection array are temporally and/or spatially averaged during the photo-integration time period thereof, thereby reducing the speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide such a method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the spatial phase modulation techniques that can be used to carry out the method include, for example: mechanisms for moving the relative position/motion of a cylindrical lens array and laser diode array, including reciprocating a pair of rectilinear cylindrical lens arrays relative to each other, as well as rotating a cylindrical lens array ring structure about each PLIM employed in the PLIIM-based system; rotating phase modulation discs having multiple sectors with different refractive indices to effect different degrees of phase delay along the wavefront of the PLIB transmitted (along different optical paths) towards the object to be illuminated; acousto-optical Bragg-type cells for enabling beam steering using ultrasonic waves; ultrasonically-driven deformable mirror structures; a LCD-type spatial phase modulation panel; and other spatial phase modulation devices.

Another object of the present invention is to provide such a method and apparatus, wherein the transmitted planar laser illumination beam (PLIB) is spatially phase modulated along the planar extent thereof according to a (random or periodic) spatial phase modulation function

(SPMF) prior to illumination of the target object with the PLIB, so as to modulate the phase along the wavefront of the PLIB and produce numerous substantially different time-varying speckle-noise pattern at the image detection array, and temporally and spatially average these speckle-noise patterns at the image detection array during the photo-integration time period thereof to reduce the RMS power of observable speckle-pattern noise.

Another object of the present invention is to provide such a method and apparatus, wherein the spatial phase modulation techniques that can be used to carry out the first generalized method of despeckling include, for example: mechanisms for moving the relative position/motion of a cylindrical lens array and laser diode array, including reciprocating a pair of rectilinear cylindrical lens arrays relative to each other, as well as rotating a cylindrical lens array ring structure about each PLIM employed in the PLIIM-based system; rotating phase modulation discs having multiple sectors with different refractive indices to effect different degrees of phase delay along the wavefront of the PLIB transmitted (along different optical paths) towards the object to be illuminated; acousto-optical Bragg-type cells for enabling beam steering using ultrasonic waves; ultrasonically-driven deformable mirror structures; a LCD-type spatial phase modulation panel; and other spatial phase modulation devices.

Another object of the present invention is to provide such a method and apparatus, wherein a pair of refractive cylindrical lens arrays are micro-oscillated relative to each other in order to spatial phase modulate the planar laser illumination beam prior to target object illumination.

Another object of the present invention is to provide such a method and apparatus, wherein a pair of light diffractive (e.g. holographic) cylindrical lens arrays are micro-oscillated relative to each other in order to spatial phase modulate the planar laser illumination beam prior to target object illumination.

Another object of the present invention is to provide such a method and apparatus, wherein a pair of reflective elements are micro-oscillated relative to a stationary refractive cylindrical lens array in order to spatial phase modulate a planar laser illumination beam prior to target object illumination.

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination (PLIB) is micro-oscillated using an acoustic-optic modulator in order to spatial phase modulate the PLIB prior to target object illumination.

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination (PLIB) is micro-oscillated using a piezo-electric driven deformable mirror structure in order to spatial phase modulate said PLIB prior to target object illumination.

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination (PLIB) is micro-oscillated using a refractive-type phase-modulation disc in order to spatial phase modulate said PLIB prior to target object illumination.

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination (PLIB) is micro-oscillated using a phase-only type LCD-based phase modulation panel in order to spatial phase modulate said PLIB prior to target object illumination.

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination (PLIB) is micro-oscillated using a refractive-type cylindrical lens array ring structure in order to spatial phase modulate said PLIB prior to target object illumination

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination (PLIB) is micro-oscillated using a diffractive-type cylindrical lens array ring structure in order to spatial intensity modulate said PLIB prior to target object illumination.

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination (PLIB) is micro-oscillated using a reflective-type phase modulation disc structure in order to spatial phase modulate said PLIB prior to target object illumination.

Another object of the present invention is to provide such a method and apparatus, wherein a planar laser illumination (PLIB) is micro-oscillated using a rotating polygon lens structure which spatial phase modulates said PLIB prior to target object illumination.

Another object of the present invention is to provide a second generalized method of speckle-noise pattern reduction and particular forms of apparatus therefor based on reducing the temporal coherence of the planar laser illumination beam before it illuminates the target object by applying temporal intensity modulation techniques during the transmission of the PLIB towards the target.

Another object of the present invention is to provide such a method and apparatus, based on the principle of temporal intensity modulating the transmitted planar laser illumination beam (PLIB) prior to illuminating a target object (e.g. package) therewith so that the object is illuminated with a spatially coherent-reduced planar laser beam and, as a result, numerous substantially different time-varying speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these speckle-noise patterns to be temporally averaged and possibly spatially averaged over the photo-integration time period and the RMS power of observable speckle-noise pattern reduced.

Another object of the present invention is to provide a novel method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the method involves modulating the temporal intensity of the composite-type "transmitted" planar laser illumination beam (PLIB) prior to illuminating an object (e.g. package) therewith so that the object is illuminated with a temporally coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array in the IFD subsystem, thereby allowing these speckle-noise patterns to be temporally averaged and/or spatially averaged and the observable speckle-noise pattern reduced.

Another object of the present invention is to provide such a method and apparatus, wherein the transmitted planar laser illumination beam (PLIB) is temporal intensity modulated prior to illuminating a target object (e.g. package) therewith so that the object is illuminated with a temporally coherent-reduced planar laser beam and, as a result, numerous substantially different time-varying speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these speckle-noise patterns to be temporally averaged and/or spatially averaged and the observable speckle-noise patterns reduced.

Another object of the present invention is to provide a novel method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, based on temporal intensity modulating the transmitted PLIB prior to illuminating an object therewith so that the object is illuminated with a temporally coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are produced at the image detection array in the IFD subsystem over the photo-integration time period thereof, and the numerous time-varying speckle-noise patterns are temporally and/or spatially averaged during the photo-integration time period, thereby reducing the RMS power of speckle-noise pattern observed at the image detection array.

Another object of the present invention is to provide such a method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein (i) the transmitted PLIB is temporal-intensity modulated according to a temporal intensity modulation (e.g. windowing) function (TIMF) causing the phase along the wavefront of the transmitted PLIB to be modulated and numerous substantially different time-varying speckle-noise patterns produced at image detection array of the IFD Subsystem, and (ii) the numerous time-varying speckle-noise patterns produced at the image detection array are temporally and/or spatially averaged during the photo-integration time period thereof, thereby reducing the RMS power of RMS speckle-noise patterns observed (i.e. detected) at the image detection array.

Another object of the present invention is to provide such a method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein temporal intensity modulation techniques which can be used to carry out the method include, for example: visible mode-locked laser diodes (MLLDs) employed in the planar laser illumination array; electro-optical temporal intensity modulation panels (i.e. shutters) disposed along the optical path of the transmitted PLIB; and other temporal intensity modulation devices.

Another object of the present invention is to provide such a method and apparatus, wherein temporal intensity modulation techniques which can be used to carry out the first generalized method include, for example: mode-locked laser diodes (MLLDs) employed in a planar laser illumination array; electrically-passive optically-reflective cavities affixed external to the VLD of a planar laser illumination module (PLIM; electro-optical temporal intensity modulators disposed along the optical path of a composite planar laser illumination beam; laser beam frequency-hopping devices; internal and external type laser beam frequency modulation (FM) devices; and internal and external laser beam amplitude modulation (AM) devices.

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination beam is temporal intensity modulated prior to target object illumination employing high-speed beam gating/shutter principles.

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination beam is temporal intensity modulated prior to target object illumination employing visible mode-locked laser diodes (MLLDs).

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination beam is temporal intensity modulated prior to target object illumination employing current-modulated visible laser diodes (VLDs) operated in accordance with temporal intensity modulation functions (TIMFS) which exhibit a spectral harmonic constitution that results in a substantial reduction in the RMS power of speckle-pattern noise observed at the image detection array of PLIIM-based systems.

Another object of the present invention is to provide a third generalized method of speckle-noise pattern reduction and particular forms of apparatus therefor based on reducing the temporal-coherence of the planar laser illumination beam before it illuminates the target object by applying temporal phase modulation techniques during the transmission of the PLIB towards the target.

Another object of the present invention is to provide such a method and apparatus, based on the principle of temporal phase modulating the transmitted planar laser illumination beam (PLIB) prior to illuminating a target object (e.g. package) therewith so that the object is illuminated with a temporal coherent-reduced planar laser beam and, as a result, numerous

substantially different time-varying speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these speckle-noise patterns to be temporally averaged and possibly spatially averaged over the photo-integration time period and the RMS power of observable speckle-noise pattern reduced.

Another object of the present invention is to provide a novel method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the method involves modulating the temporal phase of the composite-type "transmitted" planar laser illumination beam (PLIB) prior to illuminating an object (e.g. package) therewith so that the object is illuminated with a temporal coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array in the IFD subsystem, thereby allowing these speckle-noise patterns to be temporally averaged and/or spatially averaged and the observable speckle-noise pattern reduced.

Another object of the present invention is to provide such a method and apparatus, wherein temporal phase modulation techniques which can be used to carry out the third generalized method include, for example: an optically-reflective cavity (i.e. etalon device) affixed to external portion of each VLD; a phase-only LCD temporal intensity modulation panel; and fiber optical arrays.

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination beam is temporal phase modulated prior to target object illumination employing photon trapping, delaying and releasing principles within an optically reflective cavity (i.e. etalon) externally affixed to each visible laser diode within the planar laser illumination array

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination (PLIB) is temporal phase modulated using a phase-only type LCD-based phase modulation panel prior to target object illumination

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination beam (PLIB) is temporal phase modulated using a high-density fiber-optic array prior to target object illumination.

Another object of the present invention is to provide a fourth generalized method of speckle-noise pattern reduction and particular forms of apparatus therefor based on reducing the temporal coherence of the planar laser illumination beam before it illuminates the target object by applying temporal frequency modulation techniques during the transmission of the PLIB towards the target.

Another object of the present invention is to provide such a method and apparatus, based on the principle of temporal frequency modulating the transmitted planar laser illumination beam (PLIB) prior to illuminating a target object (e.g. package) therewith so that the object is illuminated with a spatially coherent-reduced planar laser beam and, as a result, numerous substantially different time-varying speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these speckle-noise patterns to be temporally averaged and possibly spatially averaged over the photo-integration time period and the RMS power of observable speckle-noise pattern reduced.

Another object of the present invention is to provide a novel method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the method involves modulating the temporal frequency of the composite-type "transmitted" planar laser illumination beam (PLIB) prior to illuminating an object (e.g. package) therewith so that the object is illuminated with a temporally coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array in the IFD subsystem, thereby allowing these speckle-noise patterns to be temporally averaged and/or spatially averaged and the observable speckle-noise pattern reduced.

Another object of the present invention is to provide such a method and apparatus, wherein techniques which can be used to carry out the third generalized method include, for example: junction-current control techniques for periodically inducing VLDs into a mode of frequency hopping, using thermal feedback; and multi-mode visible laser diodes (VLDs) operated just above their lasing threshold.

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination beam is temporal frequency modulated prior to target object illumination employing drive-current modulated visible laser diodes (VLDs) into modes of frequency hopping and the like.

Another object of the present invention is to provide such a method and apparatus, wherein the planar laser illumination beam is temporal frequency modulated prior to target object illumination employing multi-mode visible laser diodes (VLDs) operated just above their lasing threshold.

Another object of the present invention is to provide such a method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein the spatial intensity modulation techniques that can be used to carry out the method include, for example: mechanisms for moving the relative position/motion of a spatial intensity modulation array (e.g. screen) relative to a cylindrical lens array and/or a

laser diode array, including reciprocating a pair of rectilinear spatial intensity modulation arrays relative to each other, as well as rotating a spatial intensity modulation array ring structure about each PLIM employed in the PLIIM-based system; a rotating spatial intensity modulation disc; and other spatial intensity modulation devices.

Another object of the present invention is to provide a fifth generalized method of speckle-noise pattern reduction and particular forms of apparatus therefor based on reducing the spatial-coherence of the planar laser illumination beam before it illuminates the target object by applying spatial intensity modulation techniques during the transmission of the PLIB towards the target.

Another object of the present invention is to provide such a method and apparatus, wherein the wavefront of the transmitted planar laser illumination beam (PLIB) is spatially intensity modulated prior to illuminating a target object (e.g. package) therewith so that the object is illuminated with a spatially coherent-reduced planar laser beam and, as a result, numerous substantially different time-varying speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these speckle-noise patterns to be temporally averaged and possibly spatially averaged over the photo-integration time period and the RMS power of observable speckle-noise pattern reduced.

Another object of the present invention is to provide such a method and apparatus, wherein spatial intensity modulation techniques can be used to carry out the fifth generalized method including, for example: a pair of comb-like spatial filter arrays reciprocated relative to each other at a high-speeds; rotating spatial filtering discs having multiple sectors with transmission apertures of varying dimensions and different light transmittivity to spatial intensity modulate the transmitted PLIB along its wavefront; a high-speed LCD-type spatial intensity modulation panel; and other spatial intensity modulation devices capable of modulating the spatial intensity along the planar extent of the PLIB wavefront.

Another object of the present invention is to provide such a method and apparatus, wherein a pair of spatial intensity modulation (SIM) panels are micro-oscillated with respect to the cylindrical lens array so as to spatial-intensity modulate the planar laser illumination beam (PLIB) prior to target object illumination.

Another object of the present invention is to provide a sixth generalized method of speckle-noise pattern reduction and particular forms of apparatus therefor based on reducing the spatial-coherence of the planar laser illumination beam after it illuminates the target by applying spatial intensity modulation techniques during the detection of the reflected/scattered PLIB.

Another object of the present invention is to provide a novel method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array

of a PLIIM-based system, wherein the method is based on spatial intensity modulating the composite-type "return" PLIB produced by the composite PLIB illuminating and reflecting and scattering off an object so that the return PLIB detected by the image detection array (in the IFD subsystem) constitutes a spatially coherent-reduced laser beam and, as a result, numerous time-varying speckle-noise patterns are detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these time-varying speckle-noise patterns to be temporally and spatially-averaged and the RMS power of the observed speckle-noise patterns reduced.

Another object of the present invention is to provide such a method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein (i) the return PLIB produced by the transmitted PLIB illuminating and reflecting/scattering off an object is spatial-intensity modulated (along the dimensions of the image detection elements) according to a spatial-intensity modulation function (SIMF) so as to modulate the phase along the wavefront of the composite return PLIB and produce numerous substantially different time-varying speckle-noise patterns at the image detection array in the IFD Subsystem, and also (ii) temporally and spatially average the numerous time-varying speckle-noise patterns produced at the image detection array during the photo-integration time period thereof, thereby reducing the RMS power of the speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide such a method and apparatus, wherein the composite-type "return" PLIB (produced when the transmitted PLIB illuminates and reflects and/or scatters off the target object) is spatial intensity modulated, constituting a spatially coherent-reduced laser light beam and, as a result, numerous time-varying speckle-noise patterns are detected over the photo-integration time period of the image detection array in the IFD subsystem, thereby allowing these time-varying speckle-noise patterns to be temporally and/or spatially averaged and the observable speckle-noise pattern reduced.

Another object of the present invention is to provide such a method and apparatus, wherein the return planar laser illumination beam is spatial-intensity modulated prior to detection at the image detector.

Another object of the present invention is to provide such a method and apparatus, wherein spatial intensity modulation techniques which can be used to carry out the sixth generalized method include, for example: high-speed electro-optical (e.g. ferro-electric, LCD, etc.) dynamic spatial filters, located before the image detector along the optical axis of the camera subsystem; physically rotating spatial filters, and any other spatial intensity modulation element arranged before the image detector along the optical axis of the camera subsystem, through which the received PLIB beam may pass during illumination and image detection

operations for spatial intensity modulation without causing optical image distortion at the image detection array.

Another object of the present invention is to provide such a method of and apparatus for reducing the power of speckle-noise patterns observable at the electronic image detection array of a PLIIM-based system, wherein spatial intensity modulation techniques which can be used to carry out the method include, for example: a mechanism for physically or photo-electronically rotating a spatial intensity modulator (e.g. apertures, irises, etc.) about the optical axis of the imaging lens of the camera module; and any other axially symmetric, rotating spatial intensity modulation element arranged before the entrance pupil of the camera module, through which the received PLIB beam may enter at any angle or orientation during illumination and image detection operations.

Another object of the present invention is to provide a seventh generalized method of speckle-noise pattern reduction and particular forms of apparatus therefor based on reducing the temporal coherence of the planar laser illumination beam after it illuminates the target by applying temporal intensity modulation techniques during the detection of the reflected/scattered PLIB.

Another object of the present invention is to provide such a method and apparatus, wherein the composite-type "return" PLIB (produced when the transmitted PLIB illuminates and reflects and/or scatters off the target object) is temporal intensity modulated, constituting a temporally coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these time-varying speckle-noise patterns to be temporally and/or spatially averaged and the observable speckle-noise pattern reduced. This method can be practiced with any of the PLIM-based systems of the present invention disclosed herein, as well as any system constructed in accordance with the general principles of the present invention.

Another object of the present invention is to provide such a method and apparatus, wherein temporal intensity modulation techniques which can be used to carry out the method include, for example: high-speed temporal modulators such as electro-optical shutters, pupils, and stops, located along the optical path of the composite return PLIB focused by the IFD subsystem; etc.

Another object of the present invention is to provide such a method and apparatus, wherein the return planar laser illumination beam is temporal intensity modulated prior to image detection by employing high-speed light gating/switching principles.

Another object of the present invention is to provide a seventh generalized speckle-noise pattern reduction method of the present invention, wherein a series of consecutively captured

digital images of an object, containing speckle-pattern noise, are buffered over a series of consecutively different photo-integration time periods in the hand-held PLIIM-based imager, and thereafter spatially corresponding pixel data subsets defined over a small window in the captured digital images are additively combined and averaged so as to produce spatially corresponding pixels data subsets in a reconstructed image of the object, containing speckle-pattern noise having a substantially reduced level of RMS power.

Another object of the present invention is to provide such a generalized method, wherein a hand-held linear-type PLIIM-based imager is manually swept over the object (e.g. 2-D bar code or other graphical indicia) to produce a series of consecutively captured digital 1-D (i.e. linear) images of an object over a series of photo-integration time periods of the PLIIM-Based Imager, such that each linear image of the object includes a substantially different speckle-noise pattern which is produced by natural oscillatory micro-motion of the human hand relative to the object during manual sweeping operations of the hand-held imager.

Another object of the present invention is to provide such a generalized method, wherein a hand-held linear-type PLIIM-based imager is manually swept over the object (e.g. 2-D bar code or other graphical indicia) to produce a series of consecutively captured digital 1-D (i.e. linear) images of an object over a series of photo-integration time periods of the PLIIM-Based Imager, such that each linear image of the object includes a substantially different speckle-noise pattern which is produced the forced oscillatory micro-movement of the hand-held imager relative to the object during manual sweeping operations of the hand-held imager.

Another object of the present invention is to provide "hybrid" despeckling methods and apparatus for use in conjunction with PLIIM-based systems employing linear (or area) electronic image detection arrays having vertically-elongated image detection elements, i.e. having a high height-to-width (H/W) aspect ratio.

Another object of the present invention is to provide a PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a micro-oscillating cylindrical lens array micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent to produce spatial-incoherent PLIB components and optically combines and projects said spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting structure micro-oscillates the PLB components transversely along the direction orthogonal to said planar extent, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the spatially-incoherent components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a first micro-oscillating light

reflective element micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent to produce spatially-incoherent PLIB components, a second micro-oscillating light reflecting element micro-oscillates the spatially-incoherent PLIB components transversely along the direction orthogonal to said planar extent, and wherein a stationary cylindrical lens array optically combines and projects said spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the spatially incoherent components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein an acousto-optic Bragg cell micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent to produce spatially-incoherent PLIB components, a stationary cylindrical lens array optically combines and projects said spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting structure micro-oscillates the spatially-incoherent PLIB components transversely along the direction orthogonal to said planar extent, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by spatially incoherent PLIB components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a high-resolution deformable mirror (DM) structure micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent to produce spatially-incoherent PLIB components, a micro-oscillating light reflecting element micro-oscillates the spatially-incoherent PLIB components transversely along the direction orthogonal to said planar extent, and wherein a stationary cylindrical lens array optically combines and projects the spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by said spatially incoherent PLIB components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a micro-oscillating cylindrical lens array micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent to produce spatially-incoherent PLIB components which are optically combined and projected onto the same points on the surface of an object to be illuminated, and a micro-oscillating light reflective structure micro-oscillates the spatially-incoherent PLIB components transversely along the direction orthogonal to said planar extent as well as the field of view

(FOV) of a linear (1D) image detection array having vertically-elongated image detection elements, whereby said linear CCD detection array detects time-varying speckle-noise patterns produced by the spatially incoherent PLIB components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a micro-oscillating cylindrical lens array micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent and produces spatially-incoherent PLIB components which are optically combined and project onto the same points of an object to be illuminated, a micro-oscillating light reflective structure micro-oscillates transversely along the direction orthogonal to said planar extent, both PLIB and the field of view (FOV) of a linear (1D) image detection array having vertically-elongated image detection elements, and a PLIB/FOV folding mirror projects the micro-oscillated PLIB and FOV towards said object, whereby said linear image detection array detects time-varying speckle-noise patterns produced by the spatially incoherent PLIB components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a phase-only LCD-based phase modulation panel micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent and produces spatially-incoherent PLIB components, a stationary cylindrical lens array optically combines and projects the spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting structure micro-oscillates the spatially-incoherent PLIB components transversely along the direction orthogonal to said planar extent, and a linear (1D) CCD image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the spatially incoherent PLIB components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a multi-faceted cylindrical lens array structure rotating about its longitudinal axis within each PLIM micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent and produces spatially-incoherent PLIB components therealong, a stationary cylindrical lens array optically combines and projects the spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting structure micro-oscillates the spatially-incoherent PLIB components transversely along the direction orthogonal to said planar extent, and a linear (1D) image detection array with vertically-elongated image detection

elements detects time-varying speckle-noise patterns produced by the spatially incoherent PLIB components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIIM-based system with an integrated speckle-pattern noise reduction subsystem, wherein a multi-faceted cylindrical lens array structure within each PLIM rotates about its longitudinal and transverse axes, micro-oscillates a planar laser illumination beam (PLIB) laterally along its planar extent as well as transversely along the direction orthogonal to said planar extent, and produces spatially-incoherent PLIB components along said orthogonal directions, and wherein a stationary cylindrical lens array optically combines and projects the spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the spatially incoherent PLIB components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIIM-based system with an integrated hybrid-type speckle-pattern noise reduction subsystem, wherein a high-speed temporal intensity modulation panel temporal intensity modulates a planar laser illumination beam (PLIB) to produce temporally-incoherent PLIB components along its planar extent, a stationary cylindrical lens array optically combines and projects the temporally-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting element micro-oscillates the PLIB transversely along the direction orthogonal to said planar extent to produce spatially-incoherent PLIB components along said transverse direction, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the temporally and spatially incoherent PLIB components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIIM-based system with an integrated hybrid-type speckle-pattern noise reduction subsystem, wherein an optically-reflective cavity (i.e. etalon) externally attached to each VLD in the system temporal phase modulates a planar laser illumination beam (PLIB) to produce temporally-incoherent PLIB components along its planar extent, a stationary cylindrical lens array optically combines and projects the temporally-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting element micro-oscillates the PLIB transversely along the direction orthogonal to said planar extent to produce spatially-incoherent PLIB components along said transverse direction, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the temporally and spatially incoherent PLIB components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIIM-based system with an integrated hybrid-type speckle-pattern noise reduction subsystem, wherein each visible mode locked laser diode (MLLD) employed in the PLIM of the system generates a high-speed pulsed (i.e. temporal intensity modulated) planar laser illumination beam (PLIB) having temporally-incoherent PLIB components along its planar extent, a stationary cylindrical lens array optically combines and projects the temporally-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting element micro-oscillates PLIB transversely along the direction orthogonal to said planar extent to produce spatially-incoherent PLIB components along said transverse direction, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the temporally and spatially incoherent PLIB components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIIM-based system with an integrated hybrid-type speckle-pattern noise reduction subsystem, wherein the visible laser diode (VLD) employed in each PLIM of the system is continually operated in a frequency-hopping mode so as to temporal frequency modulate the planar laser illumination beam (PLIB) and produce temporally-incoherent PLIB components along its planar extent, a stationary cylindrical lens array optically combines and projects the temporally-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflecting element micro-oscillates the PLIB transversely along the direction orthogonal to said planar extent and produces spatially-incoherent PLIB components along said transverse direction, and a linear (1D) image detection array with vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the temporally and spatial incoherent PLIB components reflected/scattered off the illuminated object.

Another object of the present invention is to provide PLIIM-based system with an integrated hybrid-type speckle-pattern noise reduction subsystem, wherein a pair of micro-oscillating spatial intensity modulation panels modulate the spatial intensity along the wavefront of a planar laser illumination beam (PLIB) and produce spatially-incoherent PLIB components along its planar extent, a stationary cylindrical lens array optically combines and projects the spatially-incoherent PLIB components onto the same points on the surface of an object to be illuminated, and wherein a micro-oscillating light reflective structure micro-oscillates said PLIB transversely along the direction orthogonal to said planar extent and produces spatially-incoherent PLIB components along said transverse direction, and a linear (1D) image detection array having vertically-elongated image detection elements detects time-varying speckle-noise patterns produced by the spatially incoherent PLIB components reflected/scattered off the illuminated object.

Another object of the present invention is to provide method of and apparatus for mounting a linear image sensor chip within a PLIIM-based system to prevent misalignment between the field of view (FOV) of said linear image sensor chip and the planar laser illumination beam (PLIB) used therewith, in response to thermal expansion or cycling within said PLIIM-based system

Another object of the present invention is to provide a novel method of mounting a linear image sensor chip relative to a heat sinking structure to prevent any misalignment between the field of view (FOV) of the image sensor chip and the PLIA produced by the PLIA within the camera subsystem, thereby improving the performance of the PLIIM-based system during planar laser illumination and imaging operations.

Another object of the present invention is to provide a camera subsystem wherein the linear image sensor chip employed in the camera is rigidly mounted to the camera body of a PLIIM-based system via a novel image sensor mounting mechanism which prevents any significant misalignment between the field of view (FOV) of the image detection elements on the linear image sensor chip and the planar laser illumination beam (PLIB) produced by the PLIA used to illuminate the FOV thereof within the IFD module (i.e. camera subsystem).

Another object of the present invention is to provide a novel method of automatically controlling the output optical power of the VLDs in the planar laser illumination array of a PLIIM-based system in response to the detected speed of objects transported along a conveyor belt, so that each digital image of each object captured by the PLIIM-based system has a substantially uniform "white" level, regardless of conveyor belt speed, thereby simplifying the software-based image processing operations which need to subsequently carried out by the image processing computer subsystem.

Another object of the present invention is to provide such a method, wherein camera control computer in the PLIIM-based system performs the following operations: (i) computes the optical power (measured in milliwatts) which each VLD in the PLIIM-based system must produce in order that each digital image captured by the PLIIM-based system will have substantially the same "white" level, regardless of conveyor belt speed; and (2) transmits the computed VLD optical power value(s) to the micro-controller associated with each PLIA in the PLIIM-based system.

Another object of the present invention is to provide a novel method of automatically controlling the photo-integration time period of the camera subsystem in a PLIIM-based imaging and profiling system, using object velocity computations in its LDIP subsystem, so as to ensure that each pixel in each image captured by the system has a substantially square aspect ratio, a requirement of many conventional optical character recognition (OCR) programs.

Another object of the present invention is to provide a novel method of and apparatus for automatically compensating for viewing-angle distortion in PLIIM-based linear imaging and profiling systems which would otherwise occur when images of object surfaces are being captured as object surfaces, arranged at skewed viewing angles, move past the coplanar PLIB/FOV of such PLIIM-based linear imaging and profiling systems, configured for top and side imaging operations.

Another object of the present invention is to provide a novel method of and apparatus for automatically compensating for viewing-angle distortion in PLIIM-based linear imaging and profiling systems by way of dynamically adjusting the line rate of the camera (i.e. IFD) subsystem, in automatic response to real-time measurement of the object surface gradient (i.e. slope) computed by the camera control computer using object height data captured by the LDIP subsystem.

Another object of the present invention is to provide a PLIIM-based linear imager, wherein speckle-pattern noise is reduced by employing optically-combined planar laser illumination beams (PLIB) components produced from a multiplicity of spatially-incoherent laser diode sources.

Another object of the present invention is to provide a PLIIM-based hand-supportable linear imager, wherein a multiplicity of spatially-incoherent laser diode sources are optically combined using a cylindrical lens array and projected onto an object being illuminated, so as to achieve a greater the reduction in RMS power of observed speckle-pattern noise within the PLIIM-based linear imager.

Another object of the present invention is to provide such a hand-supportable PLIIM-based linear imager, wherein a pair of planar laser illumination arrays (PLIAs) are mounted within its hand-supportable housing and arranged on opposite sides of a linear image detection array mounted therein having a field of view (FOV), and wherein each PLIA comprises a plurality of planar laser illumination modules (PLIMs), for producing a plurality of spatially-incoherent planar laser illumination beam (PLIB) components.

Another object of the present invention is to provide such a hand-supportable PLIIM-based linear imager, wherein each spatially-incoherent PLIB component is arranged in a coplanar relationship with a portion of the FOV of the linear image detection array, and an optical element (e.g. cylindrical lens array) is mounted within the hand-supportable housing, for optically combining and projecting the plurality of spatially-incoherent PLIB components through its light transmission window in coplanar relationship with the FOV, and onto the same points on the surface of an object to be illuminated.

Another object of the present invention is to provide such a hand-supportable PLIIM-based linear imager, wherein by virtue of such operations, the linear image detection array detects time-varying speckle-noise patterns produced by the spatially-incoherent PLIB components reflected/scattered off the illuminated object, and the time-varying speckle-noise patterns are time-averaged at the linear image detection array during the photo-integration time period thereof so as to reduce the RMS power of speckle-pattern noise observable at the linear image detection array.

Another object of the present invention is to provide a PLIIM-based systems embodying speckle-pattern noise reduction subsystems comprising a linear (1D) image sensor with vertically-elongated image detection elements, a pair of planar laser illumination modules (PLIMs), and a 2-D PLIB micro-oscillation mechanism arranged therewith for enabling both lateral and transverse micro-movement of the planar laser illumination beam (PLIB).

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating cylindrical lens array and a micro-oscillating PLIB reflecting mirror configured together as an optical assembly for the purpose of micro-oscillating the PLIB laterally along its planar extent as well as transversely along the direction orthogonal thereto, so that during illumination operations, the PLIB is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism

arranged with each PLIM, and employing a stationary PLIB folding mirror, a micro-oscillating PLIB reflecting element, and a stationary cylindrical lens array configured together as an optical assembly as shown for the purpose of micro-oscillating the PLIB laterally along its planar extent as well as transversely along the direction orthogonal thereto, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating cylindrical lens array and a micro-oscillating PLIB reflecting element configured together as shown as an optical assembly for the purpose of micro-oscillating the PLIB laterally along its planar extent as well as transversely along the direction orthogonal thereto, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal (i.e. transverse) thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical

bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating high-resolution deformable mirror structure, a stationary PLIB reflecting element and a stationary cylindrical lens array configured together as an optical assembly as shown for the purpose of micro-oscillating the PLIB laterally along its planar extent as well as transversely along the direction orthogonal thereto, so that during illumination operation, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal (i.e. transverse) thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating cylindrical lens array structure for micro-oscillating the PLIB laterally along its planar extend, a micro-oscillating PLIB/FOV refraction element for micro-oscillating the PLIB and the field of view (FOV) of the linear image sensor transversely along the direction orthogonal to the planar extent of the PLIB, and a stationary PLIB/FOV folding mirror configured together as an optical assembly as shown for the purpose of micro-oscillating the PLIB laterally along its planar extent while micro-oscillating both the PLIB and FOV of the linear image sensor transversely along the direction orthogonal thereto, so that during illumination operation, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal (i.e. transverse) thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating cylindrical lens array structure for micro-oscillating the PLIB laterally along its planar extend, a micro-oscillating PLIB/FOV reflection element for micro-oscillating the PLIB and the field of view (FOV) of the linear image sensor transversely along the direction orthogonal to the planar extent of the PLIB, and a stationary PLIB/FOV folding mirror configured together as an optical assembly as shown for the purpose of micro-oscillating the PLIB laterally along its planar extent while micro-oscillating both the PLIB and FOV of the linear image sensor transversely along the direction orthogonal thereto, so that during illumination operation, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a phase-only LCD phase modulation panel, a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element, configured together as an optical assembly as shown for the purpose of micro-oscillating the PLIB laterally along its planar extent while micro-oscillating the PLIB transversely along the direction orthogonal thereto, so that during illumination operation, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal (i.e. transverse) thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-

varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating multi-faceted cylindrical lens array structure, a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element configured together as an optical assembly as shown, for the purpose of micro-oscillating the PLIB laterally along its planar extent while micro-oscillating the PLIB transversely along the direction orthogonal thereto, so that during illumination operation, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a 2-D PLIB micro-oscillation mechanism arranged with each PLIM, and employing a micro-oscillating multi-faceted cylindrical lens array structure (adapted for micro-oscillation about the optical axis of the VLD's laser illumination beam and along the planar extent of the PLIB) and a stationary cylindrical lens array, configured together as an optical assembly as shown, for the purpose of micro-oscillating the PLIB laterally along its planar extent while micro-oscillating the PLIB transversely along the direction orthogonal thereto, so that during illumination operation, the PLIB transmitted from each PLIM

is spatial phase modulated along the planar extent thereof as well as along the direction orthogonal thereto, causing the phase along the wavefront of each transmitted PLIB to be modulated in two orthogonal dimensions and numerous substantially different time-varying speckle-noise patterns to be produced at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a hybrid-type PLIB modulation mechanism arranged with each PLIM, and employing a temporal-intensity modulation panel, a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element configured together as an optical assembly as shown, for the purpose of temporal intensity modulating the PLIB uniformly along its planar extent while micro-oscillating the PLIB transversely along the direction orthogonal thereto, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof during micro-oscillation along the direction orthogonal thereto, thereby producing numerous substantially different time-varying speckle-noise patterns at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a hybrid-type PLIB modulation mechanism arranged with each PLIM, and employing a temporal-intensity modulation panel, a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element configured together as an optical assembly as shown, for the purpose of temporal intensity modulating the PLIB uniformly along its planar extent while micro-oscillating the PLIB transversely along the direction

orthogonal thereto, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof during micro-oscillation along the direction orthogonal thereto, thereby producing numerous substantially different time-varying speckle-noise patterns at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a hybrid-type PLIB modulation mechanism arranged with each PLIM, and employing a visible mode-locked laser diode (MLLD), a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element configured together as an optical assembly as shown, for the purpose of producing a temporal intensity modulated PLIB while micro-oscillating the PLIB transversely along the direction orthogonal to its planar extent, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof during micro-oscillation along the direction orthogonal thereto, thereby producing numerous substantially different time-varying speckle-noise patterns at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a hybrid-type PLIB modulation mechanism arranged with each PLIM, and employing a visible laser diode (VLD) driven into a high-speed frequency hopping mode, a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element configured together as an optical assembly as shown, for the purpose of producing a temporal frequency modulated PLIB while micro-oscillating the PLIB transversely

along the direction orthogonal to its planar extent, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof during micro-oscillation along the direction orthogonal thereto, thereby producing numerous substantially different time-varying speckle-noise patterns at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a PLIIM-based system embodying an speckle-pattern noise reduction subsystem, comprising (i) an image formation and detection (IFD) module mounted on an optical bench and having a linear (1D) image sensor with vertically-elongated image detection elements characterized by a large height-to-width (H/W) aspect ratio, (ii) a pair of planar laser illumination modules (PLIMs) mounted on the optical bench on opposite sides of the IFD module, and (iii) a hybrid-type PLIB modulation mechanism arranged with each PLIM, and employing a micro-oscillating spatial intensity modulation array, a stationary cylindrical lens array, and a micro-oscillating PLIB reflection element configured together as an optical assembly as shown, for the purpose of producing a spatial intensity modulated PLIB while micro-oscillating the PLIB transversely along the direction orthogonal to its planar extent, so that during illumination operations, the PLIB transmitted from each PLIM is spatial phase modulated along the planar extent thereof during micro-oscillation along the direction orthogonal thereto, thereby producing numerous substantially different time-varying speckle-noise patterns at the vertically-elongated image detection elements of the IFD Subsystem during the photo-integration time period thereof, so that these numerous time-varying speckle-noise patterns can be temporally and spatially averaged during the photo-integration time period of the image detection array, thereby reducing the RMS power level of speckle-noise patterns observed at the image detection array.

Another object of the present invention is to provide a based hand-supportable linear imager which contains within its housing, a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 1-D (i.e. linear) image detection array with vertically-elongated image detection elements and configured within an optical assembly that operates in accordance with the first generalized method of speckle-pattern noise reduction of the present invention, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a manually-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/fixed focal distance image formation optics, (ii) a manually-actuated trigger switch for manually activating the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/fixed focal distance image formation optics, (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating upon detection of an object in its IR-based object detection field, the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/fixed focal distance image formation optics, (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination arrays into a full-power mode of operation, the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object in its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame; and (iv) a LCD display panel and a data entry

keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/fixed focal distance image formation optics, (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/fixed focal distance image formation optics, (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for automatically activating the image processing computer for decode-processing upon automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a manually-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/variable focal distance image formation optics, (ii) a manually-actuated trigger switch for manually activating the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed

focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/variable focal distance image formation optics, (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating upon detection of an object in its IR-based object detection field, the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/variable focal distance image formation optics, (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination arrays into a full-power mode of operation, the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object in its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/variable focal distance image formation optics, (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer,

upon automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, and (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and fixed focal length/variable focal distance image formation optics, (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for automatically activating the image processing computer for decode-processing upon automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a manually-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and variable focal length/variable focal distance image formation optics, (ii) a manually-actuated trigger switch for manually activating the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and variable focal length/variable focal distance image formation optics, (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating upon detection of an object in its IR-based object detection field, the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch

for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and variable focal length/variable focal distance image formation optics, (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination arrays into a full-power mode of operation, the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object in its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and variable focal length/variable focal distance image formation optics, (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination arrays (driven by a set of VLD driver circuits), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a linear image detection array with vertically-elongated image detection elements and variable focal length/variable focal distance image formation optics, (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for

automatically activating the image processing computer for decode-processing upon automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a PLIIM-based image capture and processing engine for use in a hand-supportable imager.

Another object of the present invention is to provide a PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising PLIAs, and IFD (i.e. camera) subsystem and associated optical components mounted on an optical-bench/multi-layer PC board, contained between the upper and lower portions of the engine housing.

Another object of the present invention is to provide a PLIIM-based hand-supportable linear imager which contains within its housing, a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a linear image detection array with vertically-elongated image detection elements configured within an optical assembly that provides a despeckling mechanism which operates in accordance with the first generalized method of speckle-pattern noise reduction.

Another object of the present invention is to provide a PLIIM-based hand-supportable linear imager which contains within its housing, a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction.

Another object of the present invention is to provide a PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly which employs high-resolution deformable mirror (DM) structure which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction.

Another object of the present invention is to provide a PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs a high-resolution

phase-only LCD-based phase modulation panel which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction.

Another object of the present invention is to provide PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs a rotating multi-faceted cylindrical lens array structure which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction.

Another object of the present invention is to provide a PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs a high-speed temporal intensity modulation panel (i.e. optical shutter) which provides a despeckling mechanism that operates in accordance with the second generalized method of speckle-pattern noise reduction.

Another object of the present invention is to provide a PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs visible mode-locked laser diode (MLLDs) which provide a despeckling mechanism that operates in accordance with the second method generalized method of speckle-pattern noise reduction.

Another object of the present invention is to provide a PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs an optically-reflective temporal phase modulating structure (i.e. etalon) which provides a despeckling mechanism that operates in accordance with the third generalized method of speckle-pattern noise reduction.

Another object of the present invention is to provide a PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs a pair of reciprocating spatial intensity modulation panels which provide a despeckling mechanism that operates in accordance with the fifth method generalized method of speckle-pattern noise reduction.

Another object of the present invention is to provide a PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs spatial intensity modulation aperture which provides a despeckling mechanism that operates in accordance with the sixth method generalized method of speckle-pattern noise reduction.

Another object of the present invention is to provide a PLIIM-based image capture and processing engine for use in the hand-supportable imagers, presentation scanners, and the like, comprising a dual-VLD PLIA and a linear image detection array having vertically-elongated image detection elements configured within an optical assembly that employs a temporal intensity modulation aperture which provides a despeckling mechanism that operates in accordance with the seventh generalized method of speckle-pattern noise reduction.

Another object of the present invention is to provide a hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA, and a 2-D (area-type) image detection array configured within an optical assembly that employs a micro-oscillating cylindrical lens array which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and an area image detection array configured within an optical assembly which employs a micro-oscillating light reflective element that provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs an acousto-electric Bragg cell structure which provides a despeckling mechanism that operates in

accordance with the first generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs a high spatial-resolution piezo-electric driven deformable mirror (DM) structure which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs a spatial-only liquid crystal display (PO-LCD) type spatial phase modulation panel which provides a despeckling mechanism that operates in accordance with the first generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs a visible mode locked laser diode (MLLD) which provides a despeckling mechanism that operates in accordance with the second generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs an electrically-passive optically-reflective cavity (i.e. etalon) which provides a despeckling mechanism that operates in accordance with the third method generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs a pair of micro-oscillating spatial intensity modulation panels which provide a despeckling mechanism that operates in accordance with the fifth method generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs a electro-optical or mechanically rotating aperture (i.e. iris) disposed before the entrance pupil of the IFD module, which provides a despeckling mechanism that operates in accordance with the sixth method generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a hand-supportable imager having a housing containing a PLIIM-based image capture and processing engine comprising a dual-VLD PLIA and a 2-D image detection array configured within an optical assembly that employs a high-speed electro-optical shutter disposed before the entrance pupil of the IFD module, which provides a despeckling mechanism that operates in accordance with the seventh generalized method of speckle-pattern noise reduction, and which also has integrated with its housing, a

LCD display panel for displaying images captured by said engine and information provided by a host computer system or other information supplying device, and a manual data entry keypad for manually entering data into the imager during diverse types of information-related transactions supported by the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a manually-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type (i.e. 1D) image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a field of view (FOV), (ii) a manually-actuated trigger switch for manually activating the planar laser illumination array (to producing a PLIB in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon response to the manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a field of view (FOV), (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating upon detection of an object in its IR-based object detection field, the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a field of view (FOV), (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array into a full-power mode of operation (to produce a PLIB in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, in response to the automatic detection of an object in its laser-based object detection field, (iii) a manually-

activatable switch for enabling transmission of symbol character data to a host computer system upon decoding a bar code symbol within a captured image frame; and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager shown configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a field of view (FOV), (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the area-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object via ambient-light detected by object detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/fixed focal distance image formation optics with a field of view (FOV), (ii) an automatic bar code symbol detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the image processing computer for decode-processing in response to the automatic detection of an bar code symbol within its bar code symbol detection field enabled by the image sensor within the IFD module, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide a manually-activated PLIIM-based hand-supportable linear imager configured with (i) a linear -type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a field of view (FOV), (ii) a manually-actuated trigger switch for manually activating the planar laser illumination (to produce a planar laser illumination beam (PLIB) in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control

computer, in response to the manual activation of the trigger switch, and capturing images of objects (i.e. bearing bar code symbols and other graphical indicia) through the fixed focal length/fixed focal distance image formation optics, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a field of view (FOV), (ii) an IR-based object detection subsystem within its hand-supportable housing for automatically activating in response to the detection of an object in its IR-based object detection field, the planar laser illumination array (to produce a PLIB in coplanar arrangement with said FOV), the linear-type image formation and detection (IFD) module, as well as the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, (ii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to decoding a bar code symbol within a captured image frame, and (iii) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a field of view (FOV), (ii) a laser-based object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array into a full-power mode of operation (to produce a PLIB in coplanar arrangement with said FOV), the a linear-type image formation and detection (IFD) module, the image frame grabber, the image data buffer, and the image processing computer, via the camera control computer, upon automatic detection of an object in its laser-based object detection field, (iii) a manually-activatable switch for enabling transmission of symbol character data to a host computer system in response to the decoding a bar code symbol within a captured image frame, and (iv) a LCD display panel and a data entry keypad for supporting diverse types of transactions using the PLIIM-based hand-supportable imager.

Another object of the present invention is to provide an automatically-activated PLIIM-based hand-supportable linear imager configured with (i) a linear-type image formation and detection (IFD) module having a fixed focal length/variable focal distance image formation optics with a field of FOV, (ii) an ambient-light driven object detection subsystem within its hand-supportable housing for automatically activating the planar laser illumination array (to